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Date of Application: November 2, 1999
Application Number: H11-312402
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July 28, 2000

Commissioner, Patent Office Kohzoh OIKAWA

Docket Number: 2000-3059537

Att. #8

STATEMENT

I, Kazuhito Ino, a citizen of Japan, residing at Gifu-shi, Japan, hereby state that I believe the attached document is an accurate English translation of Japanese Patent Application No. 11-312402, filed on November 2, 1999, in the name of Tadayoshi KACHI, Junichi TAKEUCHI and Seiki SAKATA.

Kazuhito Ino

August 8, 2003

[Title of Document] Petition For Patent
[Reference Number] P991571
[Filing Date] November 2, 1999
[To] The Commissioner of the Patent Office
[International Patent Classification] H02J 7/34
H02M 3/00
[Title of the invention] Power Converting and Supplying Method and Apparatus, and Vehicle
[Number of the Claims] 10
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[Amount of Charge]

[Receipt Number for Advance Payment] 002956

[Amount of Payment] 21,000 Yen

[List of Documents Attached]

[Name of Document] Specification 1

[Name of Document] Drawings 1

[Name of Document] Abstract 1

[Number of General Power of Attorney] 9721048

[Official Confirmation Required/Not Required] Required

[Title of Document] Specification

[Title of the Invention] Power Converting and Supplying Method and Apparatus, and Vehicle

[Scope of the Invention]

[Claim 1] A method of converting and supplying power, wherein the method supplies a high-voltage DC output, the voltage of which is substantially equal to an output voltage of a DC power supply, and a low-voltage DC output, the voltage of which is lower than the output voltage of the DC power supply, wherein,

the DC power supply comprises a first DC power supply and a second DC power supply, which are connected in series, wherein the output voltage of the first DC power supply is equal to the output voltage of the low-voltage DC output, and the output voltage of the second DC power supply is equal to the difference between the output voltage of the high-voltage DC output and the output voltage of the first DC power supply, wherein the output from the first and second DC power supplies, which are connected each other in series, is supplied as the high-voltage DC output, and the output from the first DC power supply and an output lowered by using a DC-DC converter, which is connected to the second DC power supply, are supplied as the low-voltage DC output.

[Claim 2] A power converting and supplying apparatus, wherein the apparatus supplies a high-voltage DC output, the voltage of which is substantially equal to an output voltage of a DC power supply, and a low-voltage DC output, the voltage of which is lower than the output voltage of the DC power supply, the apparatus comprising:

a DC power supply, which comprises a first DC power supply and a second DC power supply, which are connected in series, wherein the output voltage of the first DC power supply is equal to the output voltage of the low-voltage DC output, and the output voltage of the second DC power supply is equal to the difference between the high-voltage DC output and the output voltage of the first DC power supply; and

a DC-DC converter, which is connected to the second DC power supply, wherein the DC-DC converter lowers the voltage of the second DC power supply, and wherein the DC-DC converter supplies the lowered voltage and the voltage of the first DC power supply as a low-voltage DC output.

[Claim 3] The power converting and supplying apparatus according to claim 2, wherein the DC-DC converter is a polarity-inverting type DC-DC converter, wherein the second DC power supply is connected to an input of the polarity-inverting type DC-DC converter, and the first DC power supply is connected to an output of the DC-DC converter.

[Claim 4] The power converting and supplying apparatus according to claim 2, wherein the DC-DC converter is an insulated DC-DC converter, wherein the second DC power supply is connected to an input of the insulated DC-DC converter, and the first DC power supply is connected to an output of the DC-DC converter.

[Claim 5] A method of converting and supplying power, wherein the method supplies a DC output, the voltage of which is higher than a output voltage of a DC power supply, wherein,

a DC-DC converter, which is connected to the DC power supply, outputs a voltage that corresponds to the difference between a required output voltage and the output voltage of the DC-power supply, and wherein the output voltage of the DC-power supply is added to the voltage corresponding to the voltage difference and the resultant voltage is supplied as a high-voltage output.

[Claim 6] A power converting and supplying apparatus **being characterized by** a DC power supply and a DC-DC converter connected to the DC power supply for converting an output voltage of the DC power supply to a voltage that corresponds to the difference between a required output voltage and the output voltage of the DC power supply,and wherein the apparatus adds the output voltage of the DC-DC converter to the output voltage of the DC-power suppply and outputs the resultant voltage.

[Claim 7] A method of converting and supplying power, wherein the method supplies a high-voltage DC output, the voltage of which is substantially equal to an output voltage of a battery and a low-voltage DC output, the voltage of which is lower than the output voltage of the battery, and wherein a DC power supply, the voltage of which is lower than the output voltage of the battery, is connected to an output to charge the battery, the method **being characterized in that:**

the battery is formed by connecting a first battery, the output voltage is equal to the output voltage of the low-voltage DC output, and a second battery, the output voltage of which corresponds to the difference between the high-voltage DC output and the output voltage of the first battery, in series, wherein the output from the series connection of the first and second batteries is supplied as the high-voltage DC output, and the output of the first battery and an output, the voltage of which is lowered by a DC-DC converter connected to the second battery, are supplied as the low-voltage DC output, and wherein, when the battery is charged, a DC power supply is connected to an output of the DC-DC converter, and the DC-DC converter outputs a voltage that corresponds to the difference between the charging voltage of the battery and the output voltage of the DC power supply, and wherein the battery is charged with a sum of the differential voltage and the output voltage of the DC power supply.

[Claim 8] A power converting and supplying apparatus, which supplies a high-voltage DC output, the voltage of which is substantially equal to an output voltage of a battery, and a low-voltage DC output, the voltage of which is lower than the output voltage of the battery, the apparatus **being characterized in that:**

the battery is formed by connecting a first battery, the output voltage is equal to the low-voltage DC output, and a second battery, the output voltage of which corresponds to the difference between the high-voltage DC

output and the output voltage of the first battery, in series, wherein an input terminal of a polarity-inverting type DC-DC converter in a step-down mode is connected to the second battery and an output terminal is connected to the first battery, and wherein a diode is connected in parallel to a switching element of the polarity-inverting type DC-DC converter, and wherein a switching element is connected in parallel to a fly-wheel diode.

[Claim 9] The power converting and supplying apparatus according to claim 8, **characterized in that** the parallel connecting circuits of the switching elements and the diodes are replaced by a MOSFET.

[Claim 10] A vehicle having a high-voltage DC power supply for driving a drive motor and a low-voltage DC power supply for auxiliary devices, the voltage of the low-voltage DC power supply being lower than the voltage of the high voltage DC power supply, the vehicle **being characterized in that** a supply device for the DC power supplies is the power converting and supplying apparatus as set forth in one of claims 2-4, 8, and 9.

[Detailed Description of the Invention]

[0001]

[Industrial Field of Application]

The present invention relates to a method and an apparatus for converting and supplying power, for converting a DC power to a DC power of a different voltage from that of the original one in order to supply, and a vehicle having the power converting and supplying apparatus.

[0002]

[Prior Art]

There is a prior art power converting and supplying apparatus that converts DC power to DC power of higher or lower voltage than that of the original one and supplies the converted DC power. As a DC-DC converter used in the power converting and supplying apparatus, a prior art voltage-drop type DC-DC converter is provided as shown in **Fig.** 7. In the voltage-drop type DC-DC converter, when the transistor TR is

ON, a voltage $V_I - V_O$ is applied to a coil CL, where V_I is an input voltage, V_O is an output voltage, L is the inductance of a coil CL, T_{on} is the ON duration of a transistor TR, and T_{off} is the OFF duration of the transistor TR. In that time the amount of change in current, ΔIL is expressed by $\Delta IL = \{(V_I - V_O)/L\}T_{on}$. When the transistor TR is turned off, a commutation diode D keeps the current flowing across the coil CL. In that time the amount of current change ΔIL is expressed by $\Delta IL = (V_O/L)T_{off}$. Therefore, when the current continuously flows across the coil CL, both current changes are equal to each other in a steady state, and the output voltage V_O is $\{T_{on}/(T_{on} + T_{off})\}V_I$, thereby lowering the input voltage V_I.

[0003]

Other known types of DC-DC converters include a booster type DC-DC converter and a booster/voltage-drop type DC-DC converter.

Recently, what is called hybrid motor vehicles have been designed and put to use in some cases in order to improve fuel efficiency and reduce the exhaust gas of motor vehicles. Hybrid vehicles which run with an engine (internal-combustion engine) use a running motor when they are started or when they run at a low speed, and use an engine when they run at a middle and high speed. A headlight and various kinds of units are used in the hybrid vehicle, and power supplies are necessary. The operational voltage for various kinds of units is lower than the operational voltage for the running motor. The conventional hybrid motor vehicles therefore need two power supplies, a high-voltage power supply for the running motor and a low-voltage power supply for the various kinds of units.

[0004]

A prior art apparatus is provided as shown in Fig. 8 to obtain the two power supplies. In the apparatus, an alternator 52 has a three-phase AC generator 52a and a three-phase full-wave rectifier 52b which are driven by the engine 51, and generates high-voltage DC power to charge a

battery 53. The DC-DC converter 54 lowers the voltage of the battery 53. In the apparatus, a high-voltage unit (motor) 55 is connected to the battery 53 and the DC-DC converter 54 lowers the voltage of the battery 53 to charge the low-voltage battery 56 for a low-voltage unit and supplies the lowered voltage to the low-voltage unit 57.

[0005]

As shown in Fig. 9, another apparatus is provided with two alternators 52 which are connected to the engine 51 to charge the high-voltage battery 53 and the low-voltage battery 56 respectively.

[0006]

[Problems that the Invention is to Solve]

When the apparatus in Fig. 8 is applied to a vehicle which needs two power supplies, the apparatus needs the large-capacity DC-DC converter 54 and two batteries 53 and 56.

[0007]

When the apparatus in Fig. 9 is applied, on the other hand, the apparatus is heavy and bulky because of the two alternators 52.

The present invention is to solve the above problems. The first objective of the present invention is thus to provide a power converting and supplying method, which stably supplies the desired DC power without using two batteries. The second objective is to provide a power converting and supplying apparatus thereof. The third objective is to provide a vehicle requiring tow power supplies of a high- voltage and a low-voltage and having a power converting and supplying apparatus, which enables miniaturization of a battery and a DC-DC converter and thus decreases spaces thereof.

[0008]

[Means For Solving the Problems]

To achieve the first objective, the invention as set forth in claim 1 provides a method of converting and supplying power. The method supplies a high-voltage DC

output, the voltage of which is substantially equal to an output voltage of a DC power supply, and a low-voltage DC output, the voltage of which is lower than the output voltage of the DC power supply. The DC power supply includes a first DC power supply and a second DC power supply, which are connected in series. The output voltage of the first DC power supply is equal to the output voltage of the low-voltage DC output, and the output voltage of the second DC power supply is equal to the difference between the output voltage of the high-voltage DC output and the output voltage of the first DC power supply. The output from the first and second DC power supplies, which are connected each other in series, is supplied as the high-voltage DC output, and the output from the first DC power supply and an output lowered by using a DC-DC converter, which is connected to the second DC power supply, are supplied as the low-voltage DC output. [0009]

To achieve the second objective, the invention as set forth in claim 2 provides a power converting and supplying apparatus. The apparatus supplies a high-voltage DC output, the voltage of which is substantially equal to an output voltage of a DC power supply, and a low-voltage DC output, the voltage of which is lower than the output voltage of the DC power supply. The apparatus includes a DC power supply and a DC-DC converter. The DC power supply includes a first DC power supply and a second DC power supply, which are connected in series. The output voltage of the first DC power supply is equal to the output voltage of the low-voltage DC output, and the output voltage of the second DC power supply is equal to the difference between the high-voltage DC output and the output voltage of the first DC power supply. The DC-DC converter is connected to the second DC power supply. The DC-DC converter lowers the voltage of the second DC power supply, and supplies the lowered voltage and the voltage of the first DC power supply as a low-voltage DC output.

[0010]

In the invention as set forth in claim 3, the DC-DC converter of the power converting and supplying apparatus according to claim 2 isa polarity-inverting type DC-DC converter, and the second DC power supply is connected to an input of the polarity-inverting type DC-DC converter and the first DC power supply is connected to an output of the DC-DC converter.

[0011]

In the invention as set forth in claim 4, the DC-DC converter of the power converting and supplying apparatus according to claim 2 isan insulated DC-DC converter, and the second DC power supply is connected to an input of the insulated DC-DC converter and the first DC power supply is connected to an output of the DC-DC converter.

[0012]

To achieve the first objective, the invention as set forth in claim 5 provides a method of converting and supplying power. The method supplies a DC output, the voltage of which is higher than a output voltage of a DC power supply. A DC-DC converter, which is connected to the DC power supply, outputs a voltage that corresponds to the difference between a required output voltage and the output voltage of the DC-power supply. The output voltage of the DC-power supply is added to the voltage corresponding to the voltage difference and the resultant voltage is supplied as a high-voltage output.

[0013]

To achieve the second objective, the invention as set forth in claim 6 provides a power converting and supplying apparatus that includes a DC power supply and a DC-DC converter connected to the DC power supply. The DC-DC converter converts an output voltage of the DC power supply to a voltage that corresponds to the difference between a required output voltage and the output voltage of the DC power supply. The apparatus adds the output voltage of the

DC-DC converter to the output voltage of the DC-power suppply and outputs the resultant voltage.

[0014]

To achieve the first objective, the invention as set forth in claim 7 provides a method of converting and supplying power. The method supplies a high-voltage DC output, the voltage of which is substantially equal to an output voltage of a battery and a low-voltage DC output, the voltage of which is lower than the output voltage of the battery. A DC power supply, the voltage of which is lower than the output voltage of the battery, is connected to an output to charge the battery. The battery is formed by connecting a first battery, the output voltage is equal to the output voltage of the low-voltage DC output, and a second battery, the output voltage of which corresponds to the difference between the high-voltage DC output and the output voltage of the first battery, in series. The output from the series connection of the first and second batteries is supplied as the high-voltage DC output, and the output of the first battery and an output, the voltage of which is lowered by a DC-DC converter connected to the second battery, are supplied as the low-voltage DC output. When the battery is charged, a DC power supply is connected to an output of the DC-DC converter, and the DC-DC converter outputs a voltage that corresponds to the difference between the charging voltage of the battery and the output voltage of the DC power supply. The battery is charged with a sum of the differential voltage and the output voltage of the DC power supply.

[0015]

To achieve the second objective, the invention as set forth in claim 8 provides a power converting and supplying apparatus, which supplies a high-voltage DC output, the voltage of which is substantially equal to an output voltage of a battery, and a low-voltage DC output, the voltage of which is lower than the output voltage of the battery. The battery is formed by connecting a first battery, the output

voltage is equal to the low-voltage DC output, and a second battery, the output voltage of which corresponds to the difference between the high-voltage DC output and the output voltage of the first battery, in series. An input terminal of a polarity-inverting type DC-DC converter in a step-down mode is connected to the second battery and an output terminal is connected to the first battery. A diode is connected in parallel to a switching element of the polarity-inverting type DC-DC converter. A switching element is connected in parallel to a fly-wheel diode.

[0016]

In the invention as set forth in claim 9, the power converting and supplying apparatus according to claim 8 has a MOSFET instead of the parallel connecting circuits of the switching elements and the diodes.

To achieve the third objective, the invention as set forth in claim 10 provides a vehicle having a high-voltage DC power supply for driving a drive motor and a low-voltage DC power supply for auxiliary devices. The voltage of the low-voltage DC power supply is lower than the voltage of the high voltage DC power supply. A supply device for the DC power supplies is the power converting and supplying apparatus as set forth in one of claims 2-4, 8, and 9.

[0017]

Therefore, in the invention as set forth in claims 1 and 2, the DC power supply produces such two kinds of outputs as the high-voltage DC output and the low-voltage DC output. The high-voltage DC output is supplied as a series voltage of the first DC power supply and the second DC power supply. The output of the first DC power supply and the output, which is lowered connecting the second DC power supply to the DC-DC converter, are supplied as the low-voltage DC output.

[0018]

In the invention as set forth in claim 3, when the switching element of the polarity-inverting type DC-DC

converter which is used as the DC-DC converter in the invention as set forth in claim 2 is turned on, the power supplied from the second DC power supply is partially stored in the inductance (reactor) for energy. When the switching element is turned off, the energy stored in the inductance is released and supplied as the low-voltage DC output. Also, the output of the first DC power supply is always produced as the low-voltage DC output.

[0019]

In the invention as set forth in claim 4, the insulated DC-DC converter is included as the DC-DC converter in the invention as set forth in claim 2, so that it is used as a switching power supply that must provide electric insulation between the input side device and the output side device.

[0020]

In the invention as set forth in claims 5 and 6, the DC output voltage higher than the output voltage of the DC power supply is supplied. A differential voltage between a target-boosted output voltage and the output voltage of the DC power supply is boosted using the DC-DC converter connected to the DC power supply and the target-boosted voltage is provided as a sum of the output voltage of the DC power supply and the output voltage of the DC-DC converter.

[0021]

In the invention as set forth in claim 7, voltages of a high-voltage DC output substantially equal to an output voltage of a battery and a low-voltage DC output lower than the output voltage of the battery are supplied. The output from the series connection of the first and second batteries is supplied as the high-voltage DC output. The outputs of the first battery and the output converted using a DC-DC converter connected to the second battery are supplied as a low-voltage DC output. When the battery is charged, a DC power supply is connected to an output terminal of the DC-DC converter, a differential voltage between the charged voltage of the battery and the output voltage of the DC

power supply is produced using the DC-DC converter, and the battery is charged with a sum of the differential voltage and the output voltage of the DC power supply.

[0015]

In the invention as set forth in claim 8, the output from the series connection of the first and second batteries is supplied as a high-voltage DC power. The outputs of the first battery and the output converted using a polarity-inverting type DC-DC converter connected to the second battery are supplied as a high-voltage DC power. When the battery is charged, a DC power supply is connected to an output terminal of the DC-DC converter, a differential voltage between the charged voltage of the battery and the output voltage of the DC power supply is produced using the polarity-inverting type DC-DC converter, and the battery is charged with a sum of the differential voltage and the outpu voltage of the DC power supply.

[0023]

In the invention as set forth in claim 9, MOSFETs are connected instead of the parallel connecting circuits of the switching elements and the diodes formed in the polarity-inverting type DC-DC converter in the invention as set forth in claim 8, so that MOSFETs, which are kept on in a step-down or boost mode, serves as the diodes, thereby simplifying the structure without using the diode.

[0024]

In the invention as set forth in claim 10, a vehicle has the first DC power supply for a running motor and the second DC power supply for a unit operable with a voltage lower than the output voltage of the first DC power supply, and includes the power converting and supplying apparatus as set forth in one of claims 2-4, 8, and 9 as the supply device for both the DC power supplies. Therefore, the battery and the DC-DC converter can be minimized, thereby decreasing the space thereof.

[0025]

[Embodiment of the invention]

(First Embodiment)

A first embodiment will now be described referring to Figs. 1 to 3, which illustrates a power converting and supplying apparatus for a vehicle that includes a high-voltage DC power supply for a running motor and a low-voltage DC power supply for a unit operable with a voltage lower than the output voltage of the high-voltage DC power supply.

[0026]

Fig. 1 shows a schematic block diagram of a power converting and supplying apparatus. As shown in Fig. 1, a battery assembly 1, which is a DC power supply for a vehicular driving motor, is included. The battery assembly 1 has a first battery cell 1a and a second battery cell 1b connected in series. The first battery cell 1a generates an output voltage that is the same as a desired low-voltage DC output. The second battery cell 1b generates a differential voltage between the high-voltage DC output and the output voltage of the first battery cell 1a. The voltage of the desired low-voltage DC output is substantially equal to the operational voltage (12V in this embodiment) for low-voltage units of a vehicle. The high-voltage DC output is the operational voltage (36V in this embodiment) of a running motor as a high-voltage unit. In this embodiment, the battery assembly 1 has a 36V output terminal and a 12-V intermediate terminal or tap 1c. The charge voltage of the battery assembly 1 is 36V and the charge voltage at the intermediate tap 1c is 12V.

[0027]

The battery assembly 1 is connected to an alternator 3, which includes a generator 3a and a full-wave rectifier 3b that are driven by an engine 2. While the engine 2 is running, the alternator 3 charges the battery assembly 1 with a voltage of 36V. A high-voltage unit 4 is connected to the battery assembly 1.

[0028]

The polarity-inverting type (buck boost) DC-DC

converter (hereinafter refereed to as a polarity-inverting type DC-DC converter) 5 is connected to the battery assembly 1, in which the input terminal of the converter 5 is connected to the second battery cell 1b or the 36V-12V terminal of the battery assembly 1 and the output terminal is connected to the first battery cell 1a or the 12V-0V terminal of the battery assembly 1. A low-voltage unit 6 is connected to the output terminal of the DC-DC converter 5.

[0029]

The polarity-inverting type DC-DC converter 5 has a switching element or transistor TR1, an inductor L1, a fly-wheel diode D1, a current sensor CS1, a control circuit 7 and capacitors C1 and C2.

[0030]

The transistor TR1 is proferably MOSFET (Metal Oxide Semiconductor Field Effect Transistor). The transistor TR1 is connected in series to the inductor L1. The transistor TR1 has a drain connected to a positive terminal of the battery assembly 1 and a source connected to the inductor L1. The fly-wheel diode D1 is located between a ground terminal or 0-V terminal and a node between the transistor TR1 and the inductor L1. The capacitor C1 is connected to the 36V-12V terminal of the battery assembly and the capacitor C2 is connected to the 12V-0V terminal of the battery assembly 1.

[0031]

The transistor TR1 and the current sensor CS1 are connected to the control circuit 7. Also connected to the control circuit 7 are a first voltage sensor 8 for detecting an output voltage of the high-voltage unit 4 and a second voltage sensor 9 for detecting an output voltage V_0 of the low-voltage unit 6. The control circuit 7 controls the ON/OFF switching of the transistor TR1 with a high frequency based on the output signals of the first voltage sensor 8 and the second voltage 9 in such a way that the ratio of the detected voltage of the voltage sensors 8 and 9 becomes 3:1. This makes it possible to keep the ratio of the output voltage to the high-voltage unit 4 to the output voltage to

the low-voltage unit 6 at 3:1.

[0032]

When the ratio of the ON time T_{on} of the transistor TR1 to the OFF time T_{off} is 1:2, for example, the ratio of the detected voltage of the first voltage sensor 8 to the detected voltage of the second voltage sensor 9 is 3:1. The control circuit 7 incorporates a circuit which compares the differential signal between the detected voltages of the first and second voltage sensors 8 and 9 and the output of the triangular wave oscillator and generates a drive signal to the transistor TR1. The control circuit 7 supplies the on signal and off signal in such a way that the ratio of the ON time T_{on} of the transistor TR1 to the OFF time T_{off} becomes 1:2 as long as the ratio of the detected voltages of the first and second voltage sensors 8 and 9 is 3:1, and the ratio of the detected signals is shifted from 3:1, the control circuit 7 changes the ON time T_{on} and the OFF time T_{off} to correct for the deviation.

[0033]

The operation of the aforementioned apparatus will now be discussed.

The DC-DC converter 5 has input terminals that are the 36V-12V terminal of the battery assembly 1, and 12V of the battery assembly 1 is a ground voltage in the DC-DC converter 5. Therefore, the input voltage V_I of the DC-DC converter 5 is 24V. The output voltage V_O of the DC-DC converter 5 is -12V because the output terminal of the DC-DC converter 5 is connected to the 12V-0V terminal of the battery assembly 1 and the 12V intermediate tap 1c is taken as a reference.

[0034]

When the transistor TR1 is turned on, the current flows as indicated by an arrow A in Fig. 1. This causes the inductor L1 to store the power that is supplied from the second battery cell 1b. Irrespective of the switching of the transistor TR1, the capacitor C2 is charged with the current from the first battery cell 1a and the current is

supplied to the low-voltage unit 6 from the capacitor C2.

[0035]

When the transistor TR1 is turned off while the transistor TR1 is kept on and the current is flowing in the inductor L1, the fly-wheel diode D1 is set on to keep this current. Then, the power stored in the inductor L1 is supplied as a low-voltage DC output. Therefore, the current flows as an arrow C shows in Fig. 2.

[0036]

Therefore, the power that drives the low-voltage unit 6 is supplied from both the polarity-inverting type DC-DC converter 5, which has the input terminal that is the 36V-12V terminal of the battery assembly 1, and the 12V-0V portion of the battery assembly 1. When the current supplied to the low-voltage unit 6 is 100 A, for example, a current of 67 A from the polarity-inverting type DC-DC converter 5 and a current of 33 A from the 12V-0V portion are both supplied to the low-voltage unit 6.

[0037]

When the power converting apparatus is in a steady state, the output voltage V_O is expressed by the following equation where ON time of the transistor TR1 is T_{on} and OFF time is T_{off}.

$$V_O = (T_{on}/T_{off})V_I$$

Also, an output current I_O is expressed by the following equation.

$$I_O = (V_I T_{on})^2/\{2L(T_{on} + T_{off})V_O\}$$

[0038]

The control circuit 7 controls the ON time T_{on} and OFF time T_{off} monitoring the output current I_O detected by the current sensor CS1 in such a way as to set $V_O = -V_I/2$, so that 2/3 of the total power supplied to the low-voltage unit 6 is supplied from the DC-DC converter 5 and the remaining 1/3 is supplied from the battery assembly 1, that is, the ratio of the output voltage supplied to the high-voltage unit 4 to the output voltage V_O supplied to the low-voltage unit 6 becomes 3:1. When a current of 33 A or larger is

supplied from the battery cell 1a (overloaded state), for example, the ratio of the detected voltages of the voltage sensors 8 and 9 is shifted from 3:1. In this case, after the overloaded state is released, the control circuit 7 controls the ON time T_{on} and the OFF time T_{off} in such a manner that the ratio of the detected voltages of the voltage sensors 8 and 9 becomes 3:1.

[0039]

If there is no variation in the load of the low-voltage unit 6, the ratio of the ON time T_{on} to the OFF time T_{off} does not change. Because the load of the low-voltage unit 6 frequently varies, however, the control circuit 7 controls the ON time T_{on} and the OFF time T_{off} based on detection signals from the first and second voltage sensors 8 and 9 in such a way that the ratio of the detected voltages of the voltage sensors 8 and 9 becomes 3:1.

[0040]

As shown in Fig. 3, the voltage of the output signal of the triangular wave oscillator incorporated in the control circuit periodically changes. The comparator generates a pulse signal whose level goes to high when a comparison voltage Vc based on the difference between the detection signals of the first and second voltage sensors 8 and 9 is smaller than the voltage of the output signal of the triangular wave oscillator and goes to low when the comparison voltage Vc is greater than the voltage of the output signal, and sends the pulse signal to the transistor TR1. The transistor TR1 is turned on when the pulse signal has a high level, and is turned off when the pulse signal has a low level. When the comparison voltage Vc is equal to a predetermined value Vs, the ratio of the detected voltages of both voltage sensors 8 and 9 is 3:1. At this time, the control circuit 7 outputs a pulse signal whose ratio of the ON time T_{on} to the OFF time T_{off} is 1:2. When the ratio of the detected voltages of both voltage sensors 8 and 9 is larger than 3:1, the detected voltage of the first voltage sensor 8 is relatively large and the comparison voltage Vc

is larger than the value Vs. At this time, the ON time T_{on} is controlled to be shorter. When the ratio of the detected voltages of both voltage sensors 8 and 9 is smaller than 3:1, the comparison voltage Vc is smaller than the value Vs. At this time, the ON time T_{on} is controlled to be longer.

[0041]

The capacitors C1 and C2 smooth the current from the battery assembly 1. When the capacitance of the transistor TR1 is relatively large, the capacitor C1 can be eliminated.

The first embodiment has the following advantages.

[0042]

(1) The apparatus comprises of the DC power supply (battery assembly 1) and the DC-DC converter. The DC power supply is formed by connecting the first DC power supply (first battery cell 1a) for generating the same output voltage as the low-voltage DC output in series to the second DC power supply (second battery cell 1b) for generating a differential output voltage between the high-voltage DC output and the output voltage from the first DC power supply. The DC-DC converter is connected to the second DC power supply for converting the voltage from the second DC power supply to the voltage of the first DC power supply, and supplies the converted voltage as the low-voltage DC output in conjunction with the output of the first DC power supply. Therefore, the DC-DC converter does not directly step down the high voltage of the DC power supply (battery assembly 1) to the predetermined low voltage, but steps down the output voltage which is lowered at the output voltage of the first DC power supply. Since the DC-DC converter 5 needs a small capacity, the DC-DC converter 5 can be made compact, which makes the power converting and supplying apparatus compact.

[0043]

(2) The DC power supply is formed by connecting the first battery cell 1a that outputs a voltage equal to the voltage of the low-voltage DC output in series to the second battery cell 1b that outputs a voltage which is the difference between the voltage of the high-voltage DC output

and the output voltage of the first battery cell 1a, and includes the intermediate tap 1c. Therefore, the first and second battery cell 1a and 1b may not separately formed, and it is therefore possible to easily secure the layout space for the first and second battery cells 1a and 1b.

[0044]

(3) As the polarity-inverting type DC-DC converter 5 is used for the DC-DC converter, and the input terminal of the polarity-inverting type DC-DC converter 5 is connected to the second battery cell 1b and the output terminal to the first battery cell 1a, the apparatus has a simple structure.

[0045]

(4) Because the aforementioned power converting apparatus is included in a vehicle, which needs two kinds of batteries of high-voltage and low-voltage, the battery and the DC-DC converter can be minimized and the space thereof can be decreased.

[0046]

(5) Because a part of the output of the polarity-inverting type DC-DC converter 5 is used to charge the first battery cell 1a when the discharge capacity of the first battery cell 1a drops down to or below a predetermined value, discharging the first battery cell 1a alone is suppressed.

[0047]

(Second Embodiment)

A second embodiment will now be described referring to Figs. 4 and 5. This embodiment is different from the first embodiment in a structure that an apparatus can step down or boost the supply voltage, that is, a low-voltage DC power supply connected to the output terminal in a step-down mode charges the battery assembly 1 which supplies higher output voltage than the voltage supplied by the low-voltage DC power supply. The power converting apparatus in this embodiment has a second transistor (MOSFET) TR2 in place of the fly-wheel diode D1 of the polarity-inverting type DC-DC converter 5 used in the first embodiment, and the remaining constitution is the same as the first embodiment. Members

similar to those of the first embodiment have the same numerals, and the detailed description thereof will be eliminated.

[0048]

MOSFET has a parasitic diode between its source and drain that is cathode as indicated by dotted lines in Fig. 4. Therefore, the use of MOSFETs for switching elements or the first transistor TR1 and the second transistor TR2 is equivalent to the use of a parallel circuit of a switching element and a diode. When the second transistor TR2 is kept off, the polarity-inverting type DC-DC converter 5 functions the same as the first embodiment.

[0049]

In the power converting apparatus in this embodiment, therefore, the second transistor TR2 is normally kept off and the first transistor TR1 is switched on or off in the same way as the first embodiment. When the output voltage of the battery assembly 1 falls below a predetermined voltage in accordance with discharge so that the battery is dead, an additional DC power supply 10 is connected to the output terminal of the polarity-inverting type DC-DC converter 5 as shown in Fig. 5 to charge the battery assembly 1. The additional DC power supply 10 can have the same output voltage as the output voltage of the first battery cell 1a.

[0050]

At the time of charging the battery assembly 1, the first transistor TR1 is kept off and the second transistor TR2 is switched on and off. In this case, the polarity-inverting type DC-DC converter 5 serves as a booster type DC-DC converter. The output voltage of the DC power supply 10 or the input voltage to the polarity-inverting type DC-DC converter 5 in a boost mode is expressed by V_I2 and the output voltage of the DC-DC converter 5 is expressed by V_O2. The voltage that is applied to the inductor L1 when the second transistor TR2 is on is V_I2 while the voltage that is applied to the inductor L1 when the second transistor TR2 is

off is $(V_O2 - V_I2)$. When the current continuously flows across the inductor L1, therefore, the amount of a change in the current flowing across the inductor L1 during the ON time T_{on} is substantially equal to the amount of a change in the current flowing across the inductor L1 during the OFF time T_{off}. This is shown in the following equation.

[0051]

$$(V_I2/L)T_{on} = \{(V_O2 - V_I2)/L\}T_{off}$$

Thus, $V_O2 = \{(T_{on} + T_{off})/T_{off}\}V_I2$. The control circuit 7 controls the ON/OFF switching of the second transistor TR2 in such a way that the ratio of V_O2 to V_I2 becomes 2:1. In other words, the control circuit 7 controls the second transistor TR2 in such a way that the ratio of the difference between the charge voltage of 36V of the battery assembly 1 and the output voltage of 12V of the DC power supply 10 to the output voltage of 12V of the DC power supply 10 is maintained at 2:1. As a result, the battery assembly 1 is charged with a voltage of 36V, which is the output voltage of 12V of the DC power supply 10 plus the boosted output voltage of 24V of the polarity-inverting type DC-DC converter 5.

[0052]

The second embodiment therefore has the advantages (1)-(5) of the first embodiment and the following additional advantages.

(6) The polarity-inverting type DC-DC converter 5 functions as the bi-directional, or voltage-lowering and boosting type converter. The DC power supply 10 is connected to the output terminal in a step-down mode, and the DC-DC converter 5 outputs a voltage that is the output voltage (12V) of the DC power supply 10 subtracted from the charge voltage (36V) of the battery assembly 1, and this output voltage is added to the output voltage of the DC power supply 10. The battery assembly 1 can be charged with the resultant voltage. This means that the DC power supply which supplies lower voltage than the output voltage of the battery assembly 1 can be used for charging the battery in

case that the battery is dead. Also, the battery assembly 1 can be charged using the battery installed in another vehicle which does not have two kinds of batteries but has only the conventional battery for low-voltage units

[0053]

(7) A diode is connected in parallel to a switching element of a typical polarity-inverting type DC-DC converter, a circuit that connects a switching element in parallel to a diode is included in place of the fly-wheel diode D1, and the switching elements are selectively controlled.

[0054]

(8) MOSFETs or transistors TR1 and TR2 are provided in place of parallel connecting circuits of a switching element and a diode. MOSFETs serve as diodes when they are turned off in a step-down mode or a boost mode. Therefore, the structure of the power converting apparatus is simpler than that of the power converting apparatus that has a diode.

[0055]

(Third Embodiment)

A third embodiment will now be described referring to Fig. 6. The apparatus of this embodiment is different from that of the above embodiments in a structure that the power converting apparatus has an insulated DC-DC converter that has a transformer capability. In this embodiment, a power converting and supplying apparatus that provides DC power supplies for high-voltage unit 4 and low-voltage unit 6 are illustrated as shown in the first embodiment. Members similar to those of the first embodiment have the same numerals, and the detailed description thereof will be eliminated.

[0056]

As shown in Fig. 6, the insulated DC-DC converter includes the fly-back converter 13. The input terminal of the fly-back converter 13 is connected to the second battery cell 1b or the 36V-12V terminal of the battery assembly 1, and the output terminal is connected to the low-voltage unit 6. The low-voltage unit 6 is connected to the 12V-0V

terminal of the battery assembly.

[0057]

When a transistor TR is on, electric energy is stored in a transformer T. When the transistor TR is off, on the other hand, the electric energy stored in the transformer T is discharged. Given that the number of turns of the primary winding of the transformer T is denoted by n1 and the number of turns of the secondary winding is denoted by n2, the following equation is satisfied when the secondary current continuously flows.

[0058]

$V_O = (n2/n1)(T_{on}/T_{off})V_I$

The control circuit 7 controls the ON/OFF action of the transistor TR in such a way that the output voltage V_O of the fly-back converter 13 coincides with the operational voltage of 12V for the low-voltage unit 6.

[0059]

The third embodiment has the advantages (1), (2), (4) and (5) of the first embodiment and the following additional advantages.

(9) The use of the insulated DC-DC converter 5 as the DC-DC converter permits the power converting apparatus to be used as a switching power supply that must provide electric insulation between the input side device and the output side device.

[0060]

(10) Since the insulated DC-DC converter includes the fly-back converter 13, the structure is simpler than one that has a forward converter.

The present invention may not be limited to the above embodiments and may be modified as follows.

[0061]

Instead of using the battery assembly 1 that is formed by connecting the first battery cell 1a for generating the same output voltage as the voltage of the low-voltage DC output in series to the second battery cell 1b for generating the differential voltage between the high-voltage

DC output and the output voltage of the first battery cell 1a and including the intermediate tap 1c, the first battery cell 1a and the second battery cell 1b may be arranged separately. In this case, manufacture of the battery such as wiring is more troublesome than that having the single battery assembly 1 that includes the intermediate tap 1c, however, the substantially same advantages can be obtained.

[0062]

In the first embodiment, the control circuit 7 that performs analog control of the ratio of the ON time of the transistor TR1 to the OFF time thereof based on the input of the detection signals of the voltage sensors 8 and 9 so that the ratio of the detections signals becomes 3:1 may be replaced with a control unit that has a CPU. In this case, the CPU computes the ratio of the ON time of the transistor TR1 to the OFF time thereof based on the detection signals of the first and second voltage sensors 8 and 9. Preferably, the ON/OFF switching of the transistor TR1 is controlled with high speed using, for example, PWM based on this computed ratio. Available as this CPU is a CPU that is used in an apparatus other than the power converting and supplying apparatus. In the second and third embodiments, the ON/OFF switching of the transistor using a CPU may be possible.

[0063]

In the first embodiment, the ON/OFF switching of the transistor TR1 is controlled in such a manner that the ratio of the output voltage for the high-voltage unit 4 to the output voltage V_o for the low-voltage unit 6 becomes 3:1. Instead, the first embodiment may use current sensors which respectively detect the amount of the current flowing across the inductor L1 and the amount of the current coming back to the battery cell 1a from the low-voltage unit 6. In this case, the control circuit 7 controls the transistor TR1 in such a manner that the ratio of the value of the two currents detected by the current sensors becomes a predetermined value (2:1 in the first embodiment). In the

second and third embodiments, the ON/OFF switching of the transistor TR1 may be controlled based on the detected current values.

[0064]

In the second embodiment, a parallel circuit of a bipolar transistor and a diode may be provided in place of the MOSFETs or the transistors TR1 and TR2.

[0065]

Instead of the MOSFET and the bipolar transistor, for example, other switching elements, such as an SIT (Static Induction Transistor) and a thyristor, may be used.

[0066]

In the case that the power converting apparatus is used for a vehicle, other high-voltage units than the running motor may be connected to the power converting and supplying apparatus. The power converting and supplying apparatus may be adapted for use in a vehicle that is not equipped with the running motor and needs two kinds of power supplies of high-voltage and low-voltage. or may be adapted for use in a battery-powered vehicle which does not have an engine.

[0067]

The power converting apparatus may be adapted for use in other apparatuses that need two kinds of power supplies of high-voltage and low-voltage than a vehicle.

As an insulated converter, the fly-back converter 13 may be replaced with another type of DC-DC converter that has the transformer T.

[0068]

A booster type insulated converter whose transformer T has a different turn ratio of the primary winding to the secondary winding from that of the transformer T of the step-down type converter may be used.

Other inventions, which are not claimed but can be understood from the description of the above embodiments, will now be discussed together with their advantages.

[0069]

(1) In the invention as set forth in one of claims 7-9,

the battery assembly is formed by uniting the first and second battery cells and providing an intermediate terminal (intermediate tap) as the output terminal of the first battery cell. In this case, the first and second battery cells may not be separately provided, so that the layout space may easily be secured and the manipulation may be easier.

[0070]

(2) In the invention as set forth in claim 6, the DC-DC converter includes an insulated DC-DC converter. In this case, the converter may be used as a switching power supply that must provide electric insulation between the input side device and the output side device.

[0071]

(3) In a vehicle having a high-voltage DC power supply and a low-voltage DC power supply for a low-voltage unit, which generates voltage lower than the output voltage of the high-voltage DC power supply, the power converting and supplying apparatus as set forth in one of the invention of claims 2-4, 8, and 9 is provided as the supply device for the DC power supplies. In this case, while the vehicle needs two kinds of power supplies of high voltage and low voltage, the battery assembly and the DC-DC converter can be minimized and the space thereof can be decreased.

[0072]

[Effects of the Invention]

As mentioned above, in the invention as set forth in claims 1-9, a desired DC voltage is stably provided without using two kinds of batteries.

[0073]

In the invention as set forth in claims 1-4, two kinds of power supplies, or a high-voltage DC output which is the same as the output voltage of the DC power supply and a low-voltage DC output which is lower than the output voltage of the DC power supply are provided.

[0074]

The structure in the invention as set forth in claim 3

is simple.

In the invention as set forth in claim 4, the converter may be used as a switching power supply that must provide electric insulation between the input side device and the output side device.

[0075]

In the invention as set forth in claims 5 and 6, the output voltage higher than the output voltage of the DC power supply is provided.

In the invention as set forth in claims 7 and 8, a high-voltage DC output which is the same as the output voltage of the DC power supply and a low-voltage DC output which is lower than the output voltage of the DC power supply are provided, and the battery assembly is charged by connecting the DC power supply for generating the voltage lower than the output voltage of the battery assembly to the output terminal.

[0076]

In the invention as set forth in claim 9, since MOSFETs, which are kept off in a step-down and boost mode, serves as a diode, the structure of the power converting and supplying apparatus is simpler than that having a diode in parallel to a switching element.

[0077]

In the invention as set forth in claim 10, while the vehicle needs two kinds of power supplies of high voltage and low voltage, the battery assembly and the DC-DC converter can be minimized and the space for them can be decreased.

[Brief Description of the Drawings]

[Fig. 1] A schematic block diagram according to a first embodiment.

[Fig. 2] A schematic block diagram showing the flows of currents when a transistor is off.

[Fig. 3] A diagram showing the relation between the on time and the off time of the transistor.

[Fig. 4] A schematic block diagram according to a second

embodiment.

[Fig. 5] A schematic block diagram of the power converting apparatus in Fig. 4, which is being charged.

[Fig. 6] A schematic block diagram according to a third embodiment.

[Fig. 7] A prior art circuit diagram of a voltage-drop type DC-DC converter.

[Fig. 8] A schematic block diagram of a prior art double power-supply system for a vehicle.

[Fig. 9] A schematic block diagram of another prior art double power-supply system for a vehicle.

[Description of the Reference Numerals]

1...battery assembly or a DC power supply, 1a...first battery or a first DC power supply, 1b...second battery or a second DC power supply, 5...polarity-inverting type DC-DC converter, 6...low-voltage unit, 10...insulated DC power supply, 13...fly-back converter or an insulated DC-DC converter, TR1...transistor serves as a switching element, TR2...second transistor serves as a switching element.

[Title of the Document] Abstract

[Abstract]

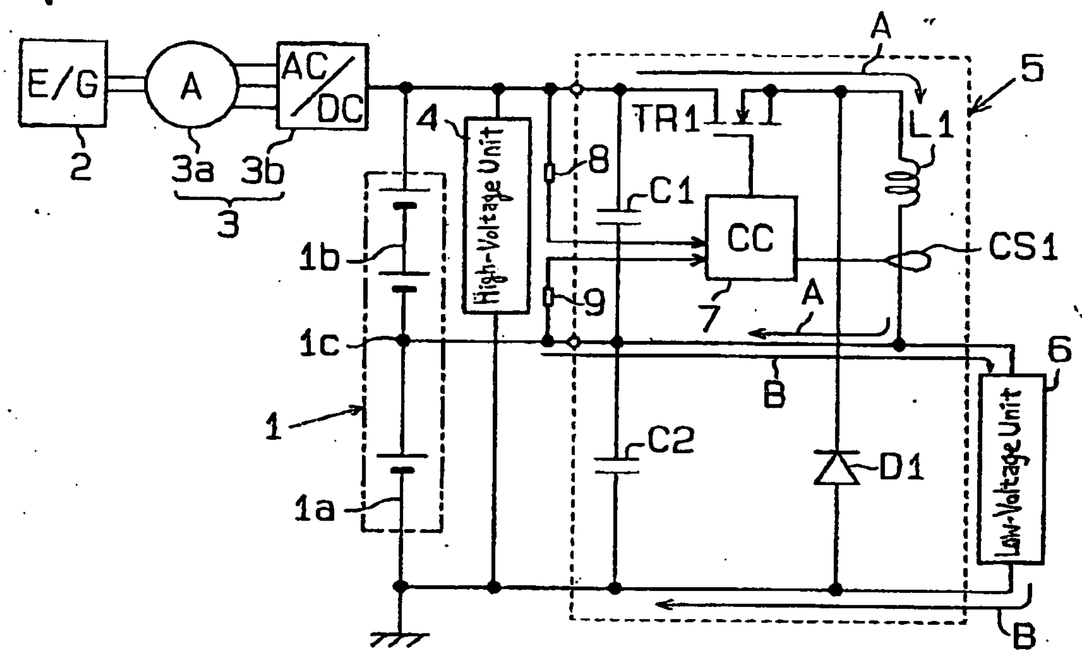
[Objective] To stably supply a desired DC voltage without using two kinds of batteries.

[Means for Solving the Problems] A battery assembly 1 connected to an alternator 3 has a 36V output terminal and an intermediate terminal 1c for generating a 12V output, and a high-voltage unit 4 is connected to the 36V-0V terminal and an input of a polarity-inverting type DC-DC converter 5 is connected to the 36V-12V terminal. The output of the DC-DC converter 5 and a low-voltage unit 6 are connected to the 12V-0V terminal of the battery assembly 1. A control circuit 7 controls the ON/OFF switching of a transistor TR1 with a high frequency based on the detection signals from a first voltage sensor 8 for detecting the voltage of the high-voltage unit 4 and a second voltage sensor 9 for detecting the low-voltage unit 6 in such a way that the ratio of the both detection voltages becomes 3:1.

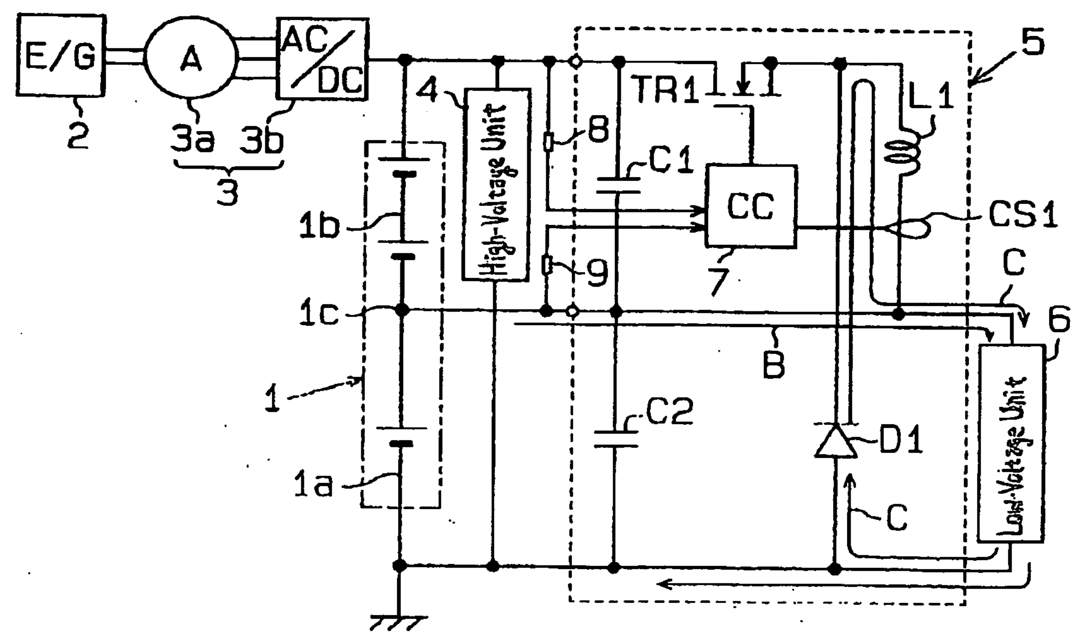
[Selected Drawing] Fig. 1

[Title of Document] Drawings

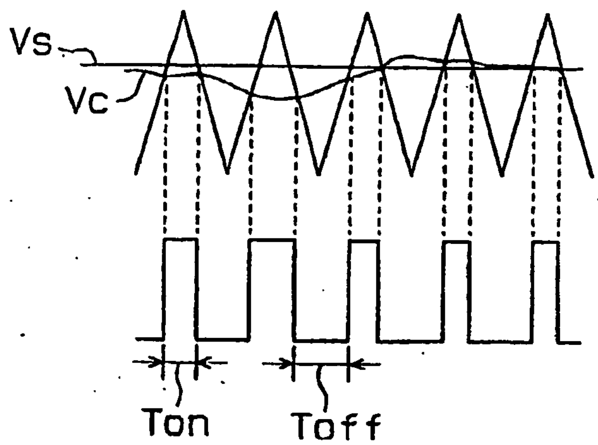
[Fig.1]



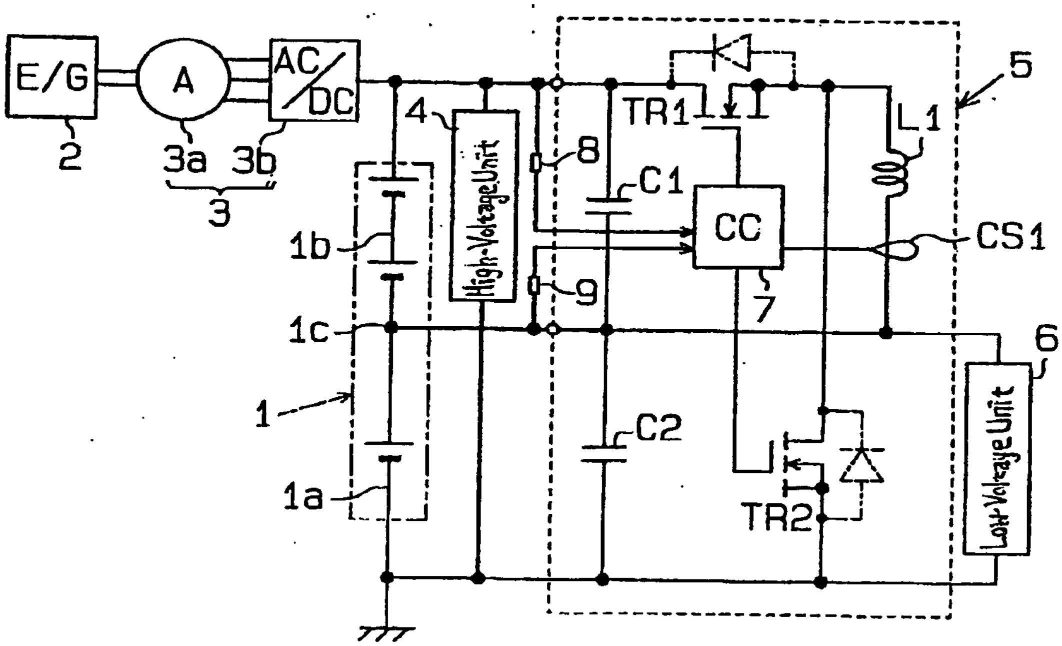
[Fig.2]



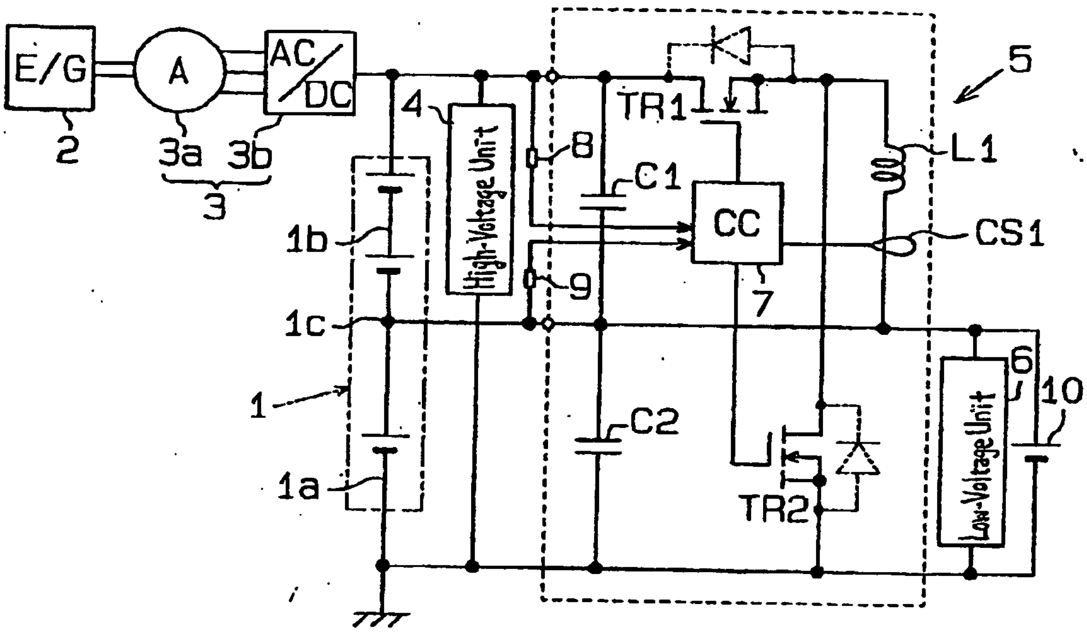
[Fig.3]


Vs
Vc
Ton
Toff

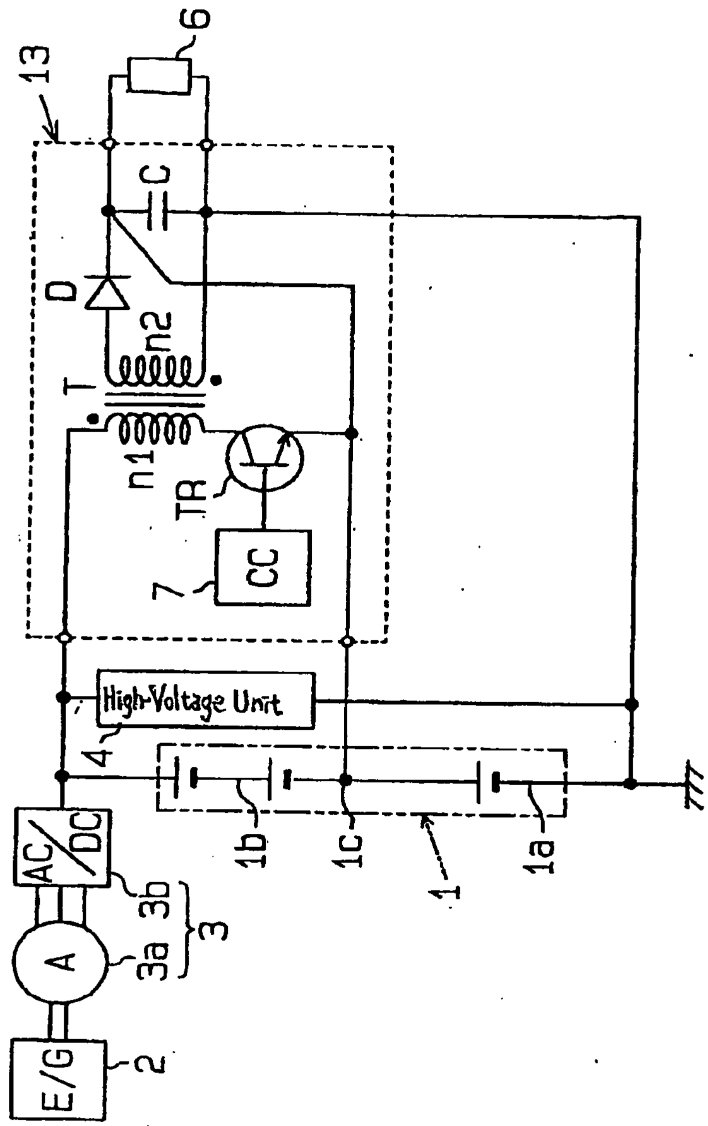
[Fig.4]


E/G
A
AC/DC
2
3a
3b
3
4
High-Voltage Unit
8
9
C1
C2
TR1
TR2
CC
7
L1
CS1
5
6
Low-Voltage Unit
1b
1c
1
1a

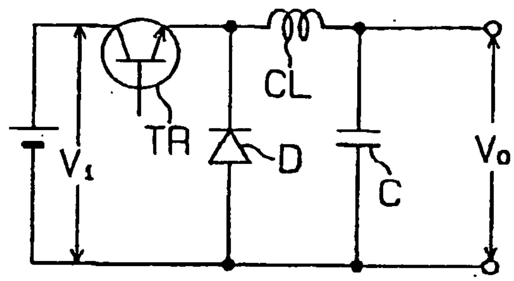
[Fig.5]


E/G
A
AC/DC
2
3a
3b
3
4
High-Voltage Unit
8
9
C1
C2
TR1
TR2
CC
7
L1
CS1
5
1b
1c
1
1a
6
Low-Voltage Unit
10

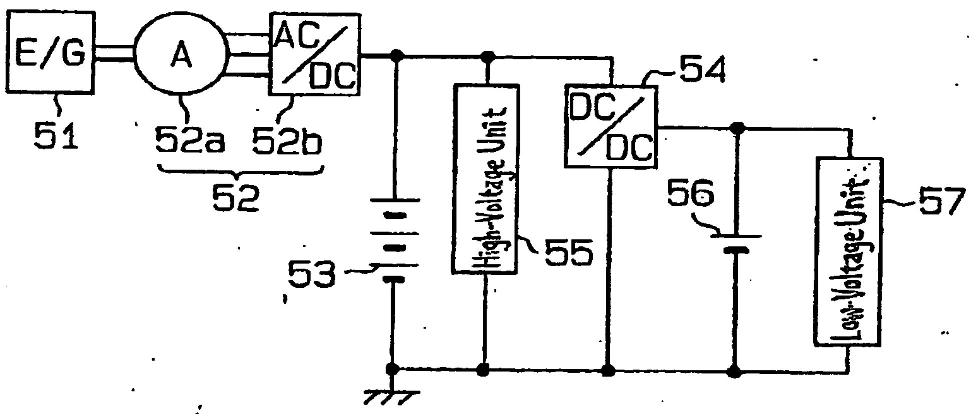
[Fig. 6]


13
6
C
D
n2
T
n1
TR
CC
7
High-Voltage Unit
4
1b
1c
1a
1
AC/DC
3b
3a
3
A
E/G
2

[Fig.7]



[Fig.8]



[Fig.9]